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## (54) FIBRE PLATE

(71) We, PHILIPS ELECTRONIC AND ASSOCIATED INDUSTRIES LIMITED, of Abacus House, 33 Gutter Lane, London, E.C.2, a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to fused fibre plates composed of large numbers of fibres which extend in parallel relationship between two end faces.

For example, when an optical system includes two optically coupled fibre-optic plates, the image formation frequently suffers from disturbances. These disturbances are mainly moiré effects caused by line structures due to the stacking of the elementary fibres or fibre bundles in the fused fibre-optic plates. In a known proposal for reducing the said disturbing effects in fibre-optic plates, attempts are made to avoid as far as possible any regularity in the stacking of the elementary fibres or fibre bundles. However, avoiding regularity in relative positioning is not simple with such large numbers of elements as are used in a fibre-optic plate. In addition, aiming at irregularity in the stacking of the fibres or fibre bundles is in conflict with the usual requirement of optimum stacking density.

Irregular stacking may adversely affect light transmission and increase the likelihood of air leaks. Compression to ensure satisfactory vacuum-tightness may also introduce inhomogeneity in the fibre bundle and hence other optical defects. The latter situation arises in the case of fibre-optic plates for use as windows of image-intensifier or camera tubes since such plates generally have to satisfy the requirement of good vacuum tightness. It is especially in such apparatus that coupling of fibre-optic plates is frequently required.

It is an object of the present invention to provide improved fibre-optic and channel plates.

The invention provides a fibre plate composed of a large number of fibres fused together in parallel relationship between two end faces, characterized in that the fibres are

arranged in a regular pattern with the addition of at least one marked fibre arranged parallel to the remaining fibres and located at or near the periphery of the plate.

Although applicable also to secondary-emissive channel plates, the invention will be described mainly with reference to fibre-optic plates.

Owing to the regularity of the stacking pattern, a fibre-optic plate can have satisfactory homogeneity, dense packing and satisfactory vacuum-tightness. When fibre-optic plates according to the invention are to be coupled, their relative angular orientation can be adjusted in a simple manner for minimum moiré disturbance with the aid of the marked fibre or fibres. Preferably in given production batches the marked fibres have fixed positions in the stacking pattern in all the fibre-optic plates used.

In a preferred embodiment the marked fibres are coloured glass fibres which are incorporated at specific positions which are left free when component elements (fibre bundles) are stacked to form a fibre rod. For this purpose, in the last of the stacking operations performed in the process of manufacture, a tubular jig of specific geometry may be used.

Embodiments of the invention will now be described, by way of example, with reference to the accompanying diagrammatic drawings in which:

Figure 1 is a cross-sectional view of a ferred elementary optical fibre,

Figure 2 is a cross-sectional view of a preferred first stacking stage for use with such elementary fibres,

Figure 3 is a cross-sectional view of a succeeding stacking stage of the manufacturing process, and

Figure 4 is a cross-sectional view of a preferred example of the last stacking stage of the manufacturing process.

Referring now to Figure 1, there is shown a cross-sectional view of a rod which may be used as the starting material for composing a fused fibre plate. The rod comprises a core 1 and a coating or cladding 2. In practice both the core and the coating are normally made of glass but, for example for use

in the ultraviolet radiation range, the coating in particular may be made of synthetic material.

For fibre-optic plates the core glass is distinguished from the coating glass by a difference in refractive index  $n$  the refractive index of the core glass being higher than that of the coating glass. For example, for the core glass  $n = 1.80$  and for the coating glass  $n = 1.49$ .

In the case of fibre plates which are to be made into channel plates but otherwise are formed and marked in the manner described in the present Specification, the cores act as temporary supports to prevent collapse of the outer tubes during drawing, and the two glasses differ in that the core glass is more readily soluble in an etchant so that after etching such a fused fibre plate is converted into a plate having open channels bounded by coating glass.

In the process of manufacturing a fused fibre plate the coating and core glasses are drawn at an elevated temperature, the coating closely surrounding the core glass rod, the cross-sectional dimensions of which rod have been held within comparatively close tolerances during manufacture. In a preferred embodiment in which the core glass rod is given a cross-section in the form of a square having a bevelled corner a mono-rod having a cross-section as shown in Figure 1 is obtained. The length of the sides of the square cross-section of such a starting rod may, for example be 40 mm while that of the chamber 3 may be about 10 mm.

The mono-rod then is drawn down to a fibre having sides of, for example, 1.7 mm whilst retaining the shape of the cross-section. The resulting mono-fibres 4 are then arranged to form a fibre bundle 5 which is shown in Figure 2 and may comprise for example 16 times 16 mono-fibres 4. The mono-fibres of the cross-section shown in Figure 1 are stacked so that the chamfered faces 3 of each group of four fibres adjoin one another. As a result, interstices 6 are formed in each of which (according to a known fibre-optic plate arrangement) there is provided a coloured fibre, or at least a fibre not transparent to the radiation to be used. The ultimate fibre-optic plate thus will have reduced transverse transmission of stray light known as EMA (extramural absorption).

If a fibre-optic plate without EMA is required, the interstices 6 can be dispensed with so that unbevelled mono-rods can be used as starting material. Thus, for example, for manufacturing fibre-optic plates in which a degree of transverse transmission is admissible or for manufacturing channel plates, rectangular (preferably square) mono-fibres can be used.

The fibre bundle 5 is drawn, while again

retaining the shape of its cross-section (which now is a square) into the form a fibre bundle 7 of a cross-section having sides of for example 1.6 mm. The resulting fibre bundles 7 are then combined to form a square-section fibre bundle 8 (Figure 3) comprising, say, 14 times 14 fibre bundles 7. The bundle 8 is drawn, while still retaining the shape of its cross-section, to produce a fibre bundle 9 the cross-section of which has sides of, say, 1.7 mm. These fibre bundles 9 are stacked in a jig 10 of octagonal cross-section as shown in Figure 4. In this preferred embodiment the cross-section of the final stacking jig is an octagon the sides of which match the transverse dimensions of the fibre bundles 9 so that a distance A indicated in Figure 4, that is to say the length of each of four alternating sides 11 of the octagon, is equal to an integral multiple of the length of the sides of the cross-section of the fibre bundles 9. Similarly the distance B determined by the sides 12 has a length equal to an integral multiple, preferably an odd multiple, of said side.

When the fibre bundles 9 are stacked in a jig of the said cross-section, triangular spaces 13 are left free the shorter sides of which are about 1.7 mm. A marked fibre 14 is inserted in at least one of these spaces. Particularly advantageous positions are the centre spaces along the sides 12. If, in the case of an odd number of layers of fibre bundles along the sides 12, marked fibres are inserted in two opposite spaces, an orientation line 15 is obtained which is at an angle of  $45^\circ$  to the sides of the fibre bundles 9 and hence to the entire cross-sectional line structure of the fibre plate. In a further preferred embodiment two marked fibres are disposed so as to subtend a right angle at the centre of the fibre plate, as is the case with a marked fibre 14 and a marked fibre 16 in Figure 4. To achieve  $45^\circ$  orientation of a second plate coupled to the first, a marked fibre of a second fibre plate must then lie on the bisector of the said right angle. In the case of an even number of spaces 13 along the sides 12, marked fibres are advantageously inserted in the two middle spaces along each of two opposite sides. Thus the  $45^\circ$  orientation line at each end extends midway between the relevant pair of marked fibres. By using coloured glass having a composition which may otherwise be equal to that of the glass of the jig 10, the marked fibres are rendered conspicuous, the centrally directed angle of the triangle accurately determining the orientation of the plate. The marked fibres may be coloured for example by adding a few tenths of a percent of cobalt to the glass. Since regular stacking of the fibres and triangular filling fibres are desirable in the manufacture of conventional fibre-optic plates, the only additional work to be done for carrying out the invention is making

some of the filling fibres of coloured glass. For practical fibre plates the octagonal shape is ground to a circular shape as indicated by a line 18.

5 When a fibre-optic plate according to the invention is to be optically coupled to another fibre-optic plate or to another optical element having a line structure, the angular orientation can unambiguously be set with  
10 minimum error without the need to, produce (and then eliminate) the moiré effect as an aid to accurate adjustment. Even if the windows engage one another in operation of the apparatus of which they form part, the  
15 orientation can thus be set with the windows spaced apart so as to avoid damage to their surfaces by mutual friction. If the optical element to be coupled is not a fibre-optic plate according to the invention but does  
20 have a structure having preferred directions, these preferred directions must be known or discernible. Thus if a fibre-optic window is used as an entrance window for a television camera tube, the wire direction of the mesh  
25 electrode is simply taken into account and an orientation different from 45° may be used. This also applies to image-forming apparatus in which a luminescent screen in the form of lines is provided.

30 Optical, in this case electron-optical, coupling of channel plates is employed in particular in manufacturing "chevron" channel intensifiers. In such devices the channels, viewed in the axial direction, each have a  
35 sharp bend for the purpose of avoiding ion feed-back through the channels or for rendering the plates optically opaque. Such a chevron channel amplifier plate may be made by coupling two channel plates each cut at an  
40 acute angle to the channel axis of a bundle. If for this purpose fibre plates according to the invention are used, moiré effects can be avoided since their marked fibres may analogously be used to indicate the direction in  
45 which the fibre channels are at an angle to the end faces.

Channel plates are usually made by a method in which tubular glass fibres filled with temporary glass cores are subjected to  
50 multi-draw processing. After the final stack has been fused it is sliced and then the said cores are etched out of the slices. In these circumstances the whole of each marked fibre must be made of a glass the etchability of which (by a selected core etchant) is at least as low as that of the coating  
55 glass.

For coupling, for example, a television camera tube having a fibre-optic plate as the  
60 entrance window and an image intensifier tube having a fibre-optic plate as the exit window, a diaphragm construction as described in (co-pending Patent Application 29355/74) (PHN 7001) may be used. In the said construction the two fibre-optic plates engage

one another under elastic pressure when in operation. Subsequent rotation of one fibre-optic plate relative to the other in the engaged position damages the windows. Furthermore, when the plates are not mechanically coupled the moiré effect cannot readily  
70 be studied and reduced to a minimum. The use of fibre-optic plates according to the invention enables optimum angular orientation to be set with the plates disengaged without  
75 the necessity of relying on the moiré effect for the adjustment. If there is no third structure or if there is only one which does not give rise to disturbance at any angular orientation, the fibre-optic plates are preferably  
80 arranged at an angle of 45° to one another.

In optical systems it may be necessary for an optical element to be rotatable about the optical axis of the system. An example is  
85 a rotatable television camera tube in which it is not possible to rotate the deflection fields around the tube. If such a camera tube has a fibre-optic window as the entrance window and the system includes a second  
90 fibre-optic window, the moiré effect is not at a minimum in every position. This problem can be mitigated by using two fibre-optic windows according to the invention, the elementary fibres of one window having  
95 transverse dimensions different from those of the other. An advantageous ratio between the transverse dimensions is, for example, about 1.4 to 1.9. Thus, inaccurate angular orientation may give rise to the said disturbances, but these are not so inconvenient  
100 as to seriously impede examination of the image. In most cases rotation is effected until optimum image orientation is found and in this optimum position the object may  
105 be oriented so that the television camera tube may be given the orientation of minimum moiré disturbance.

#### WHAT WE CLAIM IS:—

1. A fibre plate composed of a large number of fibres fused together in parallel relationship between two end faces, characterized in that the fibres are arranged in a  
115 regular pattern with the addition of at least one marked fibre arranged parallel to the remaining fibres and located at or near the periphery of the plate.

2. A fibre plate as claimed in Claim 1  
20 composed of fibre-bundles of square cross-section, the or each marked fibre being disposed in a space left free at the edge of the fibre plate by the stacking structure.

3. A fibre plate as claimed in Claim 1  
125 or Claim 2 including at least two marked fibres which each have a cross-section in the form of a right-angled triangle, the right angles of the or each pair being directed to one another whilst the line joining the  
130

vertices is at an angle of  $45^\circ$  to the line structure of the stacking pattern.

4. A fibre plate as claimed in Claim 1 or Claim 2 including an even number of pairs of marked fibres, an orientation line which is at an angle of  $45^\circ$  to the line structure of the fibre plate being a line of mirror-image symmetry for the marked fibres.

5. A fibre plate as claimed in Claim 1 or Claim 2 including two marked fibres which at the centre of the fibre plate subtend a right angle the bisector of which is at an angle of  $45^\circ$  to the line structure of the plate.

- 15 6. A fibre plate as claimed in any of the preceding claims constructed in the form of a fibre-optic plate.

- 20 7. Image forming apparatus provided with at least one fibre-optic plate as claimed in Claim 6, wherein the fibre-optic plate is optically coupled to a second fibre-optic plate having a line structure at an angle of

orientation at which the moiré effect is reduced to a minimum.

8. Image-forming apparatus as claimed in Claim 7, comprising an image-intensifier tube and a camera tube, the exit window of the image-intensifier tube and the entrance window of the camera tube each being constituted by a fibre-optic plate as claimed in Claim 6.

9. A fibre plate as claimed in any of Claims 1 to 5, constructed in the form of a channel plate produced by removing cores by etching and introducing secondary-emissive material into the resulting channels.

10. A fibre-optic plate substantially as herein described with reference to the drawings.

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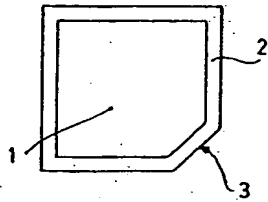


Fig. 1

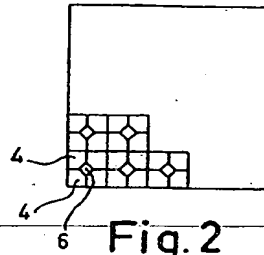


Fig. 2

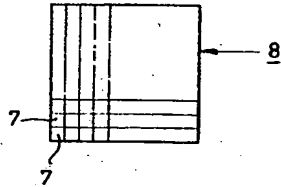


Fig. 3

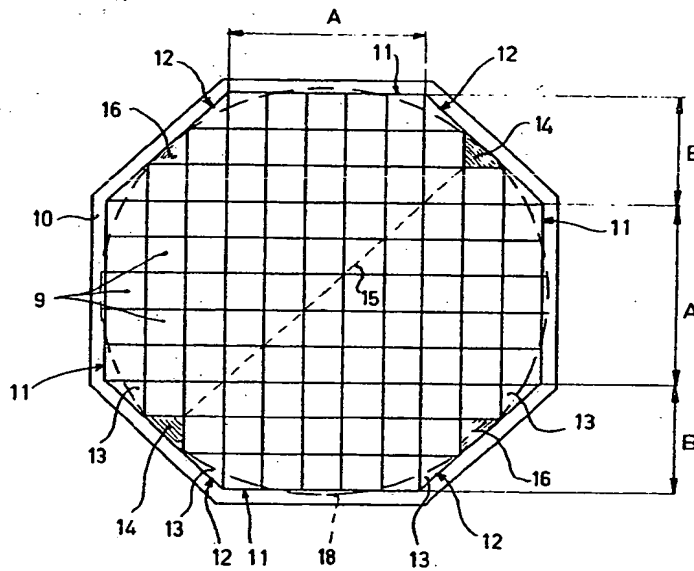


Fig. 4

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